LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA11 | Stoke Mandeville and Aylesbury

Flood risk assessment (WR-003-011)

Water resources

November 2013

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Department for Transport

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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise four parts. The first of these is a route-wide appendix (Volume 5: Appendix WR-001-000).

1.1.2 Specific appendices for each community forum area (CFA) are also provided. For the Stoke Mandeville and Aylesbury area (CFA11), these are:

- a water resources assessment (Volume 5: Appendix WR-002-011);
- a flood risk assessment (i.e. this appendix); and
- a hydraulic modelling report for the Stoke Brook to the south of Stoke Mandeville (Volume 5: Appendix WR-004-003).

1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5, Water Resources and Flood Risk Assessment Map Book.

1.2 Scope and structure of this assessment

1.2.1 This flood risk assessment (FRA) considers the assessment of flood risk in CFA11. The assessment has been carried out in accordance with the requirements of the National Planning Policy Framework (NPPF)[1] which aims to prevent inappropriate development in areas at risk of flooding and to ensure that, where development is necessary in areas at risk of flooding, it is safe without increasing flood risk elsewhere.

1.2.2 The FRA methodology and a review of the relevant local planning policy documents are provided in Section 2 of this report. The design criteria are provided in Section 3. Section 4 documents the sources of information that have been reviewed. Section 5 provides a description of the planned works within CFA11. Section 6 considers baseline flood risk and the risk of flooding to the Proposed Scheme from all relevant sources. Flood risk mitigation measures included within the Proposed Scheme are detailed in Section 7. The effect of the Proposed Scheme on the risk of flooding is considered in Section 8.

1.3 Location

1.3.1 CFA11 covers an approximate 10.5km section of the Proposed Scheme in the districts of Aylesbury Vale and Wycombe, in the county of Buckinghamshire. The area extends from just north of Nash Lee, approximately 700m east of the A4010 Risborough Road, south of Stoke Mandeville, to approximately 200m south of the A41 Bicester Road near Cranwell Farm. As shown in Figure 1, the Dunsmore, Wendover and Halton area (CFA10) is located to the south and the Waddesdon and Quainton area (CFA12) is located to the north.

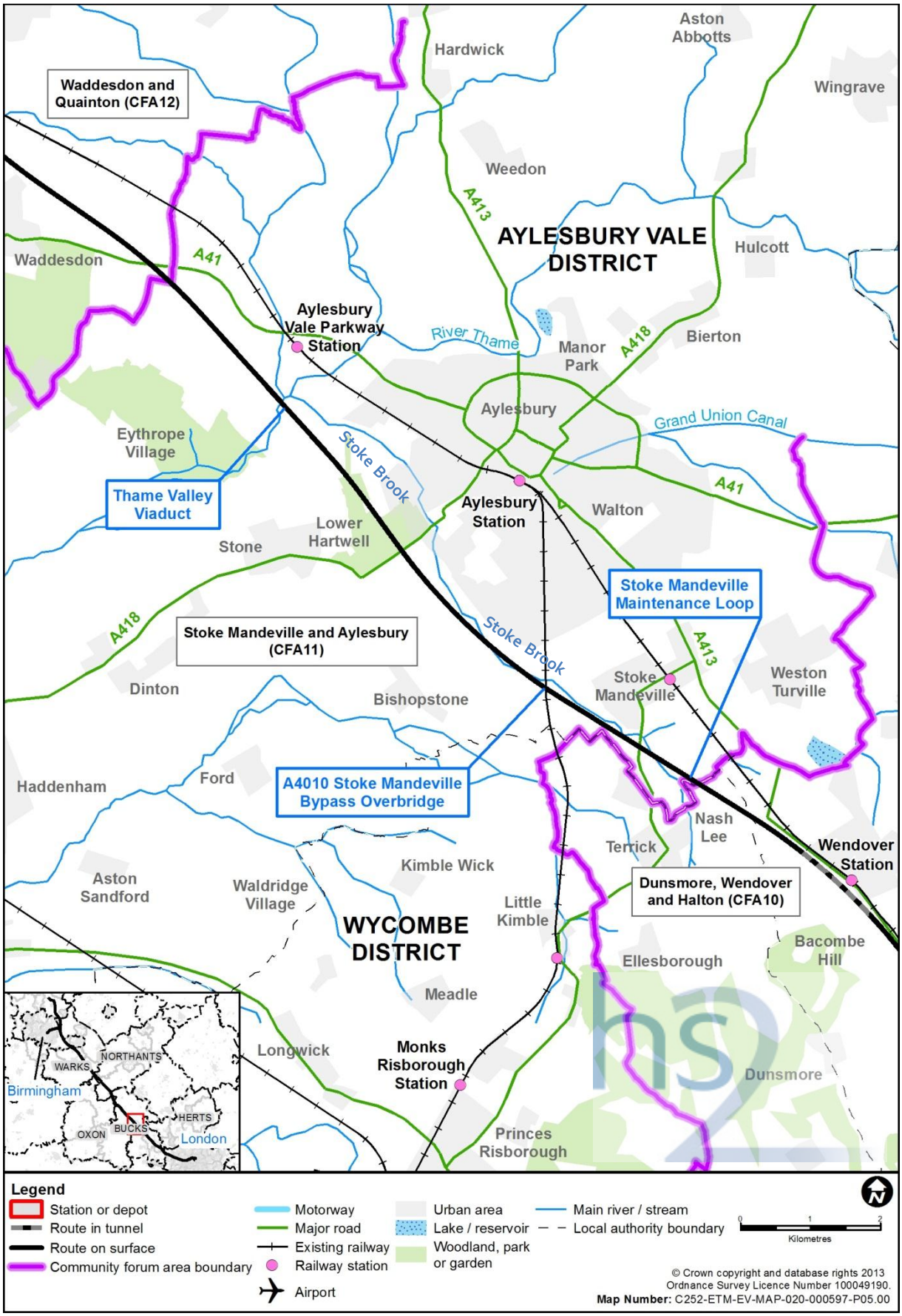
[1] Department for Communities and Local Government (2012), *National Planning Policy Framework*

1.3.2 The study area extends to a distance of 1km from the centre line of the Proposed Scheme and includes the parishes of Stoke Mandeville, Stone with Bishopstone and Hartwell, Quarrendon, Fleet Marston and Waddesdon. The corresponding council wards are Icknield, Aston Clinton, Haddenham, Waddesdon, Quarrendon, Walton Court and Hawkslade and Coldharbour.

1.3.3 The route will cross a number of primary watercourses within the study area as identified using the surface water crossing (SWC) references on Map WR-01-014 and Map WR-01-015 (Volume 5, Water Resources and Flood Risk Assessment Map Book) including:

- the Stoke Brook and its tributaries (SWC-CFA11-01 to SWC-CFA11-05);
- the Sedrup Ditch (SWC-CFA11-08), Lower Hartwell Ditch and its tributary streams close to Lower Hartwell (SWC-CFA11-09 to SWC-CFA11-11);
- the River Thame (SWC-CFA11-13); and
- the tributaries of the Fleet Marston Brook (SWC-CFA11-15 and SWC-CFA11-16).

Figure 1: Stoke Mandeville and Aylesbury area



2 Flood risk assessment methodology

2.1 Source-pathway-receptor model

2.1.1 Flood risk is assessed using the source-pathway-receptor model. In this model individual sources of flooding within the study area are identified. The primary source of flooding is rainfall, which is a direct source in the short-term (surface water flooding) and can lead to flooding from watercourses (river flooding) and overloaded man-made collection systems (sewer flooding) in the short- or medium-term. Stored rainfall, either naturally in below ground aquifers and natural lakes or artificially in impounded reservoirs and canals can lead to flooding when the storage capacity of the system is exceeded. A final source of flooding arises from tidal effects and storm surges caused by low pressure systems over the sea.

2.1.2 For there to be a risk of flooding at an individual receptor there must be a pathway linking it to the source of flooding. The pathways within the study area are assessed by reviewing national datasets that show the spatial distribution of flood risk. The associated risk magnitude is then categorised.

2.1.3 Receptors considered in this assessment include the Proposed Scheme and existing development within 1km of the route. The Proposed Scheme includes all associated permanent infrastructure. Areas of interest are identified through comparison of the national spatial datasets with the design drawings. Where a risk is identified, mitigation is proposed in line with recommendations in the NPPF.

2.1.4 Existing receptors within the study area are identified using Ordnance Survey (OS) mapping information. A high-level screening assessment is then undertaken to identify receptors that are within or in close proximity to an area of flood risk via pathways indicated using the flood risk data sources listed in Section 4.1 of this report. The vulnerability of each receptor is classified using Table 2 of the NPPF Technical Guidance Document[2].

2.1.5 The assessment then considers the vulnerability of the receptor with reference to the flood risk category of the source using Table 3 of the NPPF Technical Guidance Document and assesses whether the Proposed Scheme has any potential to influence or alter the risk of flooding to each receptor. Where such potential has been identified, mitigation is proposed based on further analysis.

2.2 Flood risk categories

2.2.1 The level of flood risk is categorised by assessing the design elements against the datasets for each source. A matrix showing the flood risk category associated with each flooding source is presented in Table 1.

[2] Department for Communities and Local Government (2012), *National Planning Policy Framework Technical Guidance*.

Table 1: Flood risk category matrix for all flooding sources

Source of flooding	Flood risk category				
	No risk	**Low**	**Medium**	**High**	**Very high**
Rivers		Flood Zone 1	Flood Zone 2	Flood Zone 3a	Flood Zone 3b
Surface water	No surface water flooding.	Surface water flooding <0.3m for 1 in 200 years event.	Surface water flooding >0.3m for 1 in 200 years event; and Surface water flooding <0.3m for 1 in 30 years event.	Surface water flooding >0.3m for 1 in 30 years event.	
Groundwater		Very low-low	Moderate	High-very high	
Drainage and sewer systems	No sewer in vicinity of site.	Surcharge point >20m from site and no pathways.	Surcharge point within 20m of site and restricted pathways.	Sewer network crosses site and pathways exist.	
Artificial sources	Outside of inundation mapping/no pathway exists.	Within inundation mapping/ pathway exists.			

2.3 Regional and local flooding planning policy documents

2.3.1 The Lead Local Flood Authority (LLFA) for CFA11 is Buckinghamshire County Council (BuCC). The recommendations from the BuCC Preliminary Flood Risk Assessment (PFRA)[3] have been reviewed in undertaking this assessment. The draft BuCC Local Flood Risk Management Strategy (LFRMS)[4] is at the consultation stage and was published in February 2013. The local authority for CFA11 is Aylesbury Vale District Council (AVDC). The AVDC core strategy[5] (referred to as the Vale of Aylesbury Plan) is at the consultation stage.

Buckinghamshire County Council Preliminary Flood Risk Assessment

2.3.2 The BuCC PFRA confirms that there are no indicative flood risk areas of national significance within Buckinghamshire. Consequently, only Stage 1 of the Flood Risk Regulations 2009[6] process (i.e. the PFRA) has been completed.

2.3.3 The most significant historical flood event in Buckinghamshire was caused by high groundwater levels across the chalk aquifers resulting in high river flows and widespread groundwater flooding in the valleys of the Chiltern Hills. The flooding

[3] Jacobs (2011), *Buckinghamshire County Council Preliminary Flood Risk Assessment.*
[4] Buckinghamshire County Council (2013), *Buckinghamshire County Council Local Flood Risk Management Strategy 2013 - 2018.*
[5] Aylesbury Vale District Council (2013), *The Vale of Aylesbury Plan Strategy 2011 – 2031 Proposed Submission (2013).*
[6] *Flood Risk Regulations 2009* (SI 2009 No.3042). London, Her Majesty's Stationery Office.

occurred in the winter of 2000/2001 and is considered to have had significant harmful consequences.

2.3.4 The BuCC PFRA recognises that the construction and engineering of the Proposed Scheme may have a significant impact upon surface water flows. For example embankments and cuttings may, without suitable design solutions, impede the flow of small watercourses and surface runoff.

Buckinghamshire County Council Local Flood Risk Management Strategy

2.3.5 The BuCC LFRMS guides the planning process in relation to flood risk across all categories. The BuCC LFRMS outlines key policies in relation to development within Buckinghamshire. Specific policies of relevance to the Proposed Scheme are:

- "Policy 6 – the LLFA will seek to reduce the risk of flooding now in a way which does not compromise the interconnected needs of the economy, society and environment in the future"; and
- "Policy 15 – sustainable drainage systems (SuDS) should be used in new developments to reduce the rate and volume of surface water. Design of SuDS to meet national standards and to be adopted by the SuDS Approval Body. SuDS are expected to provide natural removal of pollutants and sediments, promote aquifer recharge, enhanced biodiversity, add aesthetic value and be easily maintainable."

Thames Region Catchment Flood Management Plan

2.3.6 All watercourses in this area fall within the Thames Region Catchment Flood Management Plan (CFMP)[7] which covers the fluvial extent of the Thames basin. The main focus of the Thames Region CFMP revolves around the high risk of flooding to key urban centres of which the majority lie downstream of the study area and the predicted future increase in flood risk due to climate change. Restoration of culverted watercourses is a high priority for the Aylesbury area. There is a high focus on managing and reducing existing flood risk in the basin through restoring and enhancing natural floodplain capacity and utilising the potential to manage floodwater through new developments, especially within the upstream tributaries. This is of particular relevance to the Stoke Brook and Hartwell and Sedrup ditches where opportunities exist for at-source flood relief through natural floodplain enhancement.

Aylesbury Vale Water Cycle Strategy

2.3.7 The Aylesbury Vale Water Cycle Strategy[8] reviews flood risk management planning policy relevant to AVDC and outlines location specific concerns regarding flood risk management. The Aylesbury Vale Water Cycle Strategy identifies significant risks of river flooding along the River Thame and Stoke Brook and notes the presence of the Fairford Leys flood storage area to the west of Aylesbury. All proposed developments

[7] Environment Agency (2007), *Thames Region Catchment Flood Management Plan.*
[8] Halcrow (2012), *Aylesbury Vale Water Cycle Strategy*.

in the Aylesbury area will require detailed drainage strategies and SuDS proposals. Surface water should be discharged separately to ground or local watercourses without using existing public sewers. There is no surface water management plan for Aylesbury.

Aylesbury Vale Strategic Flood Risk Assessment

2.3.8 The Aylesbury Vale Level 1 Strategic Flood Risk Assessment[9] (SFRA) includes advice on planning policy within the development area and is often used as a basis for policy setting and planning decisions.

2.3.9 The AVDC SFRA identifies the need for surface water runoff management in the district due to particular concern over flood risk in the River Thame and Bear Brook catchments of which the watercourses in the study area form a part. Infiltration based SuDS are preferred as a means of surface water management particularly to the south of Aylesbury. Ground investigations are required to determine the feasibility of such techniques. In addition, opportunities are sought to enhance and supplement the existing flood storage and alleviation measures already in place for AVDC. Opportunities for source-controlled flood risk management are identified with the Stoke Brook and downstream Bear Brook catchments of particular priority. Specifically, AVDC SFRA policy indicates that:

- management of surface runoff should use site specific and strategic SuDS measures encouraging source control where possible; and
- proposed infrastructure should avoid interference with floodplain flow and storage where they cross existing river valleys unless they are also specifically designed as part of the strategic flood risk management options. Consultation with the Environment Agency is essential in such cases.

Aylesbury Town Strategic Flood Risk Assessment

2.3.10 The Aylesbury Town Level 2 SFRA[10] focusses on a more accurate definition of flood risk within the Aylesbury urban area and potential growth arcs. The document, however, also includes limited advice on planning policy within the Aylesbury urban area. Of particular interest is the southern growth arc that coincides with the study area and includes the Stoke Brook. Recommendations for potential strategic link roads apply to the Proposed Scheme (such as proposed road diversions) with the following policy recommended: "It will be necessary to design the roads in such a way that they do not have an adverse effect on flood risk. Most importantly, infrastructure built in the floodplain should have a minimised footprint and not increase flood risk elsewhere."

2.3.11 Surface water management is again a key concern within the Aylesbury Town Level 2 SFRA. Source control techniques and SuDS are recommended with development runoff restricted to baseline greenfield runoff rates.

[9] Aylesbury Vale District Council (2012), *Aylesbury Vale Level 1 Strategic Flood Risk Assessment.*
[10] Royal Haskoning (2009), *Aylesbury Town Level 2 Strategic Flood Risk Assessment.*

Vale of Aylesbury Plan

2.3.12 The Vale of Aylesbury Plan is in the consultation stage. Objective 7, which covers adaptation to and mitigation against climate change, is of specific relevance to flood risk and development and states that:

- no built greenfield development is to take place in the functional floodplain and/or Flood Zones 2 or 3, other than for essential strategic infrastructure; and
- the provision for flood protection should be improved, such as the more effective use of multi-functional green spaces to assist in flood control.

2.3.13 Policy VS11 sets out the position of the Council towards protection of environmental assets with a focus on maintaining watercourses and their settings for their biodiversity and recreational value, as well as incorporation of SuDS and flood storage areas to reduce downstream flood risk.

3 Design criteria

3.1.1 It is a requirement of the design that the Proposed Scheme shall be protected against flooding from any source during the 1 in 1,000 years return period (0.1% annual probability) rainfall event with water levels not rising closer than 1m to the top of rail level.

3.1.2 In accordance with the NPPF an allowance for climate change is included in the assessment by assuming that peak rainfall intensity will increase by 30% and that peak river flows will increase by 20%.

4 Data sources

4.1 Primary datasets

4.1.1 Consistent with the requirements of the NPPF, this assessment considers the risk of flooding from rivers, direct surface water runoff, rising groundwater, overwhelmed drainage and sewer systems and artificial sources such as reservoirs, lakes and canals.

4.1.2 The Proposed Scheme lies entirely outside the extent of flooding from the sea and therefore the risk of flooding from tidal sources is not considered in this assessment.

4.1.3 The primary datasets for each source of flooding used to assess the design elements are presented in Table 2. A high-level review of the risk of flooding and potential impacts is undertaken on the basis of these datasets across all flood sources. Where this review indicates potentially significant impacts on the risk of flooding or a risk of flooding to the route further investigation, in the form of hydraulic modelling, is undertaken.

Table 2: Flood risk assessment data sources

Source of flooding	Datasets reviewed	Data owner
Rivers	Flood zone mapping. Detailed river network. Catchment hydraulic models.	Environment Agency
Surface water	Flood Map for Surface Water (FMfSW). Local surface water flood mapping.	Environment Agency LLFA
Groundwater	Areas susceptible to groundwater flooding. 1:50,000 geological mapping (superficial and bedrock). Potential for elevated groundwater.	British Geological Survey (BGS) LLFA
Drainage and sewer systems	Sewer network plans. Lost river location plans.	Water companies (various) Local planning authority
Artificial sources	Reservoir inundation mapping (RIM) Canal infrastructure locations. Trunk water main asset plans.	Environment Agency Canal & River Trust Water companies (various)

4.2 Site familiarisation visits

4.2.1 A site familiarisation visit was undertaken in December 2012 to the Stoke Brook to visit the area of proposed works and associated tributary streams and water bodies where access was granted. A second site familiarisation visit was undertaken in May 2013 to visit the Sedrup and Hartwell ditches, as well as the River Thame and Fairford Leys flood storage area.

5 The proposed development

5.1 Topography and land use

5.1.1 The land use within the study area is predominantly agriculture and is interspersed with village settlements and isolated farmsteads and dwellings. The town of Aylesbury extends into the study area and dominates the eastern side of the Proposed Scheme along the majority of the length to the River Thame. The village of Stoke Mandeville is also located within the study area to the north of the Proposed Scheme. The villages of Stone and Upper and Lower Hartwell also lie within the study area. The topography is typified by undulating clay valleys.

5.1.2 The study area can be split into two parts of distinct character: a part comprising the urban southern extent of Aylesbury and a part that us predominantly rural. There are large areas of open space and recreational facilities within the study area including Aylesbury Park Golf Club, Hartwell House Spa (a Grade I listed building) and Hartwell House historic parkland (which is Grade II* listed). Stoke House (a Grade II listed building) and the Bucks Goat Centre also lie within the study area.

5.2 Local flood risk receptors

5.2.1 The vulnerability of each local receptor with an identified pathway within the study area is presented in Table 3. The vulnerability is classified in accordance with the recommendations of Table 2 in the NPPF Technical Guidance Document and the Scope and Methodology Report (SMR) (see Volume 5: Appendix CT-001-000/1) and the SMR Addendum (see Volume 5: Appendix CT-001-000/2).

Table 3: Vulnerability of local receptors in CFA11

Local receptor	Description	Vulnerability	Source/pathway
Triangle Business Park	Industrial estate	Less vulnerable	Surface water 30 years - deep
Stoke Grove Farm	Residential dwelling and agriculture	More vulnerable	Surface water 30 years - deep
Stoke House	Residential dwelling and historical building	More vulnerable	Surface water 30 years - deep
Bucks Goat Centre	Commercial attraction/leisure	Less vulnerable	Surface water 200 years - shallow
Old Risborough Road houses	Residential dwellings Access road only	More vulnerable	Surface water 200 years - shallow
The Paddock	Residential dwelling	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep
Stoke Mandeville village	Residential dwellings and associated infrastructure including schools, playing fields and community centre	More vulnerable	Surface water 30 years - deep Highway drainage
Ayearses Yard	Commercial units	Less vulnerable	Surface water 30 years - shallow

Local receptor	Description	Vulnerability	Source/pathway
Brook Farm	Residential dwelling and agriculture	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep
Moat Farm	Residential dwelling and agriculture	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep Groundwater - very high
Hall End	Residential dwelling and agriculture	More vulnerable	Surface water 30 years - shallow
Princes Risborough to Aylesbury Line	Rail infrastructure	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep Groundwater - very high
Aylesbury Town	Residential dwellings and associated infrastructure including schools and playing fields	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - shallow Groundwater - very high Bear Brook flood storage reservoir failure
Standalls Farm	Residential dwelling and agriculture	More vulnerable	Surface water 30 years - shallow
Sedrup Lane residential area	Residential dwellings	More vulnerable	Surface water 30 years - shallow
Sedrup Farm	Residential dwelling and agriculture	More vulnerable	Surface water 30 years - shallow
Calley Farm	Residential dwelling and agriculture	More vulnerable	Surface water 200 years - shallow
Hartwell Depot	Commercial units	Less vulnerable	Groundwater - high
Meadoway residential area	Residential dwelling, public house and telephone exchange	More vulnerable	Surface water 30 years - shallow
Hartwell Cottage	Residential dwelling	More vulnerable	Groundwater - high
Hartwell House and parkland	Hotel, leisure, historically valued buildings and parkland	More vulnerable	Surface water 30 years - shallow Groundwater - very high
Aylesbury Park Golf Club	Leisure	Less vulnerable	River flooding Flood Zone 2 Surface water 30 years - shallow Groundwater - very high
Upper Hartwell village	Residential dwellings	More vulnerable	Surface water 200 years - shallow

Local receptor	Description	Vulnerability	Source/pathway
Fairford Leys village	Residential dwellings and associated infrastructure including school and commercial centre	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - shallow Groundwater - very high Stocklake flood storage reservoir failure Bear Brook flood storage reservoir failure
Lower Hartwell village	Residential dwellings	More vulnerable	Surface water 30 years - deep Groundwater - very high
Aylesbury (west)	Residential dwellings and commercial area	More vulnerable	River flooding Flood Zone 2
Fairford Leys flood storage area	Flood defence infrastructure	Water-compatible	River flooding Flood Zone 3 Surface water 30 years - shallow Tring reservoirs failure
Aylesbury Sewage Treatment Works	Sewage treatment works	Less vulnerable	River flooding Flood Zone 2 Groundwater - very high
Putlowes	Residential dwelling and agriculture	More vulnerable	Surface water 30 years - shallow
Putlowes Drive residential area	Residential dwellings	More vulnerable	Surface water 200 years - shallow
Berryfields Farm	Residential dwelling and agriculture	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep
Old Rectory Cottage	Residential dwelling	More vulnerable	Groundwater - very high
Hunters Farm industrial estate	Commercial units	Less vulnerable	Surface water 30 years - shallow and 200 years - deep Groundwater- very high
Upper Cranwell Farm	Residential dwelling and agriculture	More vulnerable	Surface water 200 years - shallow
Fleet Marston Farm	Residential dwelling and agriculture	More vulnerable	Surface water 30 years - shallow and 200 years - deep

5.3 Description of the Proposed Scheme

5.3.1 The study area covers an approximately 10.5km section of the Proposed Scheme. The route will commence just north of Nash Lee and continue north-west under A4010 Risborough Road, Marsh Lane and the Princes Risborough to Aylesbury Line. The route will pass to the west of Stoke Mandeville and Aylesbury, passing under the A418 Oxford Road and will then proceed to the east of Hartwell House. It will cross the River Thame to the north-east of Aylesbury, heading north-west across the Aylesbury Vale to exit the area south of the A41 Bicester Road.

5.3.2 The key elements of the Proposed Scheme are shown on Map CT-06-040 to Map CT-06-047 (Volume 2, CFA11 Map Book).

5.3.3 The Proposed Scheme will leave CFA10 on the Stoke Mandeville south embankment which continues for a further 1.4km in this area and is up to 5m high. A maintenance loop (approximately 1.2km long) will extend from CFA10 to the south of Stoke Mandeville. The route will then descend into the Aylesbury south cutting which is approximately 2.3km long and up to 7m deep. This section of the Proposed Scheme extends from just north of B4009 Nash Lee Road to north of the Princes Risborough to Aylesbury Line on the south-western edge of Aylesbury.

5.3.4 The Proposed Scheme will continue to the Aylesbury south embankment and Aylesbury north cutting section which comprises an embankment approximately 1.3km long and up to 6m high and a cutting approximately 750m long and up to 5m deep, followed by the Oxford Road embankment which is approximately 900m long and up to 4m high. Landscape earthworks will be included on both sides of the Proposed Scheme from the start of the embankment to just south of the A418 Oxford Road.

5.3.5 The Proposed Scheme will continue into the Thame Valley viaduct and adjacent earthworks section, comprising a cutting approximately 1km long and up to 6m deep, a 100m long embankment up to 5m high, a viaduct approximately 1km long and which will be up to 6m above ground, another embankment approximately 0.1km up to 2m high and a further cutting approximately 800m long and up to 4m deep. This section runs from the Aylesbury Park Golf Club, west of Aylesbury, to north of the River Thame.

5.3.6 The final 1.2km of the Proposed Scheme will be the Bicester Road embankment.

6 Existing flood risk

6.1 Historical flooding incidents

6.1.1 The AVDC SFRA identifies specific historical flooding events within the study area arising from the River Thame, Stoke Brook and Bear Brook. The River Thame was flooded in 1947 between the existing railway bridge and Stone whilst the Stoke Brook was flooded in 1947, 1954, 1963 and 1968 downstream of the Princes Risborough to Aylesbury Line to the River Thame. Channel improvement works were undertaken in 1977 and 1978 to alleviate flooding in the Stoke Brook and included a diversion of the Hartwell ditches directly to the Bear Brook.

6.1.2 The BuCC PFRA identifies two instances of flooding from non-river or unidentified sources within the study area on Lower Road south of Stoke Mandeville Hospital and on Bicester Road near Berryfields Bridge. The former is likely to have arisen due to intense rainfall combined with a lack of surface water collection capacity, whilst the latter is likely to have occurred due to backing up of the Fleet Marston Brook behind the culvert which carries the brook beneath Bicester Road.

6.2 Risk of flooding from rivers

6.2.1 The route will cross the floodplains of the Stoke Brook, the Sedrup Ditch, the Hartwell ditches and the River Thame within CFA11.

6.2.2 In addition, the route will cross three watercourses in the wider River Thame catchment to the north-west of the River Thame viaduct which are defined within the Environment Agency river network, but do not have associated flood zones. These watercourses are assessed within the risk of flooding from surface water section (Section 6.3 of this report).

Stoke Brook

6.2.3 Together with its tributaries, the Stoke Brook has a combined catchment size of approximately 5km^2 at Risborough Road. The route will occupy an area of approximately 16,500m^2 of both Flood Zone 2 and Flood Zone 3 upstream of the Risborough Road culvert. The route will cross the valley parallel to the natural flow direction at two locations, as shown on Map WR-01-014, G4-H5 (Volume 5, Water Resources and Flood Risk Assessment Map Book). The Stoke Brook is formed of dual channels at this location. An artificial feeder channel carries water to the former mill pond at Stoke House and the smaller, natural channel winds along the valley bottom. Two tributaries of the Stoke Brook will also be crossed by the route at this location. Hydraulic modelling has been undertaken to define the flooding baseline and assess impacts arising from the Proposed Scheme and to propose mitigation.

6.2.4 Design elements within the Proposed Scheme that will lie within the area at risk of flooding from the Stoke Brook are the Stoke Mandeville south embankment (including maintenance loop) and the Footpath ELL/20 overbridge as shown on Map CT-06-040 (Volume 2,CFA11 Map Book).

6.2.5 Downstream of the current location of Risborough Road, the Footpath SMA/9 accommodation overbridge, the Stoke Mandeville Bypass overbridge and the Princes Risborough to Aylesbury Line overbridge will all cross the floodplain of the Stoke Brook.

Hydrology and hydraulic modelling

6.2.6 The flood zones downstream of the Princes Risborough to Aylesbury Line were updated based on hydraulic modelling for the Stoke Brook undertaken by Peter Brett Associates and Atkins in 2008 on behalf of the Environment Agency[11]. The extent of flooding is predicted to remain predominantly in-channel for flood events up to a 1 in 1000 years return period (0.1% annual probability). However, upstream of the Princes Risborough to Aylesbury Line, the flood zones are not based on hydraulic modelling.

6.2.7 A hydraulic model of the Stoke Brook has therefore been created to gain a more detailed understanding of the flooding mechanisms upstream of Risborough Road. The model was constructed using the one-dimensional and two-dimensional domain and hydrodynamic linking capabilities of InfoWorks RS. The topography of the model is based upon 20cm resolution light detection and ranging (LiDAR) data within the one-dimensional component and re-sampled 50cm resolution LiDAR data within the two-dimensional component.

6.2.8 The purpose of the hydraulic model is to refine the understanding of existing hydraulic characteristics and flood extents of the Stoke Brook upstream of Risborough Road to inform the design and the FRA.

6.2.9 Inflow hydrographs were constructed using the Revitalised Flood Hydrograph (ReFH) rainfall-runoff methodology for the flood events with return periods of 20 (5% annual probability), 100 (1% annual probability) and 1,000 (0.1% annual probability) years and further simulations at the two lower return periods including an inflation of 20% on design flows to allow for future climate change.

6.2.10 The two channels and tributaries of the Stoke Brook were modelled using one-dimensional cross sections extracted from the ground model with details of hydraulic structures observed and measured where possible during the site walkover survey. A two-dimensional mesh was used to represent areas of significant floodplain flow between the two channels of the Stoke Brook and along the southern floodplain. A more detailed description of the modelling methodology can be found in Volume 5: Appendix WR-004-003.

Flood risk to Proposed Scheme

6.2.11 The Proposed Scheme will cross the Stoke Brook at a number of locations. Flood water levels were extracted from the model at each location and are presented in Table 4, together with top of rail levels for the Proposed Scheme. At all locations the Proposed Scheme is at least 2m above the 1 in 1,000 years return period (0.1% annual probability) flood water level.

[11] Peter Brett Associates and Atkins (2008), Bear Brook & Upper Thame Flood Risk Mapping Study. Environment Agency.

Table 4: Modelled maximum flood water levels and corresponding top of rail levels for the Proposed Scheme

		Modelled maximum flood water level (m AOD)			
Surface water crossing reference	**Description**	**1 in 20 years**	**1 in 100 years (+20%)**	**1 in 1,000 years**	**Top of rail level**
SWC-CFA11-01	Nash Lee tributary foot of western side embankment	103.03	103.14	103.25	105.4
SWC-CFA11-18	Stoke Brook upstream of Footpath ELL/20 overbridge	102.96	103.13	103.33	105.7
SWC-CFA11-03	Mill Stream foot of western side embankment	101.83	101.93	101.95	104.7
SWC-CFA11-04	Stoke Brook foot of western side embankment	100.25	100.41	100.52	104.4
SWC-CFA11-06	Stoke Grove Farm tributary foot of western side embankment	98.33	98.45	98.67	103.7

6.2.12 The Footpath ELL/20 overbridge is raised to pass over the Proposed Scheme within the area at risk of flooding from the Stoke Brook. The footpath level will be 112m above Ordnance Datum (AOD) at the channel crossing and will be approximately 6m above the estimated 1 in 1,000 years return period (0.1% annual probability) flood water level.

6.2.13 The Footpath SMA/9 accommodation overbridge, the Stoke Mandeville Bypass overbridge and the Princes Risborough to Aylesbury Line overbridge will all cross the floodplain of the Stoke Brook between Risborough Road and the Princes Risborough to Aylesbury Line.

6.2.14 The Footpath SMA/9 accommodation overbridge will be raised to pass over the Proposed Scheme to the south of the Stoke Brook channel. The northern overbridge approach embankment will return to ground level immediately south of the Stoke Brook channel. The approach embankment lies within Flood Zone 3 of the Stoke Brook. Although there is consequently a potential risk of flooding, the risk to the existing footpath is reduced due to the raised embankment.

6.2.15 The Stoke Mandeville Bypass overbridge will be raised on embankment where it will pass over the Stoke Brook floodplain. The minimum level of the embankment within the floodplain width is over 91.5m and is significantly above the floodplain level at the edge of Flood Zone 2 (taken from LiDAR data) of 89m AOD. There will be no significant risk of flooding to the Stoke Mandeville Bypass overbridge.

6.2.16 The Princes Risborough to Aylesbury Line embankment will be raised above the existing embankment height to enable sufficient clearance of the Proposed Scheme. The flood zone outlines suggest that the existing embankment does not overtop in the extreme (1 in 1,000 years return period) event and consequently this element is not considered to be at significant risk of flooding.

Sedrup Ditch

6.2.17 The Sedrup Ditch (SWC-CFA11-08) has a catchment size of approximately 2km^2 at the crossing point with the route, as shown on Map CT-06-043, E7 (Volume 2, CFA11 Map Book). The flood zones in the area have been refined by the Environment Agency using detailed hydraulic modelling of the River Thame and Stoke Brook catchments. This modelling includes the enhancements to the Stoke Brook channel capacity undertaken in 1978. As a result of the downstream channel improvements and the low flow volumes expected, the hydraulic model indicates that floodwaters would remain in channel for all events up to the 1 in 1,000 years return period (0.1% annual probability) flood. Consequently, the flood zones are confined to the channel of the Sedrup Ditch.

6.2.18 The design element within the Proposed Scheme that will lie within the area currently at risk of flooding from the Sedrup Ditch is the Aylesbury embankment.

Flood risk to Proposed Scheme

6.2.19 The Environment Agency has provided detailed hydraulic model results from a one-dimensional-two-dimensional hydrodynamically linked model. The model uses ISIS for the one-dimensional (channel flow) component of the model and TUFLOW for the two-dimensional (floodplain flow) component. The model shows that the stream would stay in bank for all events up to the 1 in 1,000 years return period (0.1% annual probability) flood.

6.2.20 The baseline estimates of maximum flood water levels at the crossing are presented in Table 5. The top of rail level at the channel crossing will be 83.7m AOD.

Table 5: Sedrup Ditch model details (critical 12.25hr storm duration)

	1% annual probability flood	**1% annual probability including climate change allowance**	**0.1% annual probability flood**
Peak channel flow	0.48m^3/s	0.58m^3/s	0.80m^3/s
Baseline flood level	77.75m AOD	77.83m AOD	77.96m AOD

6.2.21 Comparison of the Proposed Scheme with the predicted flood water levels from the hydraulic model results shows that the top of rail level will be at least 5.7m above the predicted 1 in 1,000 years return period (0.1% annual probability) flood water level. As a result the risk of river flooding on the operational portion of the Proposed Scheme will be less than 0.1% (low risk). There are no other elements to the Proposed Scheme that will potentially be at risk of flooding from the Sedrup Ditch.

Hartwell ditches

6.2.22 The Hartwell ditches (SWC-CFA11-09 to SWC-CFA11-11) have a combined catchment size of approximately 1km^2 at the intersection with the route. The flood zones in the area have been refined by the Environment Agency using detailed hydraulic modelling of the River Thame and Stoke Brook catchments. This modelling includes the enhancements to the Stoke Brook channel capacity undertaken in 1978 and the associated diversion of the Hartwell Ditch. As a result of the downstream channel

improvements and the low flow volumes expected, the hydraulic model indicates that floodwaters would remain in channel for all events up to the 1 in 1,000 years return period (0.1% annual probability) flood. Historical records of flooding in the Hartwell area held by the Environment Agency, however, show a substantial area of the Aylesbury Park Golf Club as flooding. Although this is likely to result from other sources, most likely high groundwater levels, Flood Zone 2 has been extended to cover this additional area. Flood Zone 3 is confined to the channels of the watercourses.

6.2.23 Design elements within the Proposed Scheme that will lie within the area currently at risk of flooding from the Hartwell ditches are the Oxford Road embankment and the Footpath SBH/32 overbridge, as shown on Map CT-06-044 (Volume 2, CFA11 Map Book).

Flood risk to Proposed Scheme

6.2.24 The Environment Agency has provided detailed hydraulic model results from a one-dimensional two-dimensional hydrodynamically linked model. The model uses ISIS for the one-dimensional (channel flow) component of the model and TUFLOW for the two-dimensional (floodplain flow) component. The model shows that the stream would stay in bank for all events up to the 1 in 1,000 years return period (0.1% annual probability) flood. Both channels of the Hartwell ditches are modelled. The modelling of the southern watercourse (Hartwell Ditch), however, commences just downstream of the route intersection. Inflows have been extracted from the model for this ditch.

6.2.25 The northern ditch (Lower Hartwell Ditch) is modelled from Lower Hartwell village upstream of the Proposed Scheme. Modelled water levels and flows, therefore, are available in the Environment Agency model. In general, flood water levels in the Lower Hartwell ditch are over 1m higher than those in the Hartwell Ditch at the point modelling commences (immediately downstream of the scheme). Consequently, the flood water level in the Lower Hartwell Ditch is used as the design flood level for the area.

6.2.26 The baseline estimates of maximum flood water levels at the crossing are presented in Table 6. The minimum top of rail level within the floodplain area will be 79.3m AOD.

Table 6: Lower Hartwell model details (critical 12.25hr storm duration)

	1% annual probability	**1% annual probability including climate change allowance**	**0.1% annual probability**
Peak channel flow Hartwell Ditch	0.193m^3/s	0.231m^3/s	0.318m^3/s
Peak channel flow Lower Hartwell Ditch	0.196m^3/s	0.235m^3/s	0.344m^3/s
Baseline flood level (Lower Hartwell Ditch)	75.21m AOD	75.25m AOD	75.34m AOD

6.2.27 Comparison of the Proposed Scheme with the predicted flood water levels from the hydraulic model results shows that the top of rail level will be at least 4m above the

predicted 1 in 1,000 years return period (0.1% annual probability) flood water level. As a result, the risk of river flooding from the Hartwell ditches on the operational portion of the Proposed Scheme will be less than 0.1% (low risk). There are no other elements to the Proposed Scheme that will potentially be at risk of flooding from the Hartwell ditches.

River Thame

6.2.28 The River Thame (SWC-CFA11-13) has a catchment size of approximately 215km^2 at the intersection with the route. The route will cross a total length of approximately 790m and 920m of Flood Zone 3 and 2 respectively perpendicular to the natural flow direction, as shown on Map WR-01-015, F5-G6 (Volume 5, Water Resources and Flood Risk Assessment Map Book).

6.2.29 Design elements that will lie within the area at risk of flooding from the River Thame are limited to the Thame Valley viaduct.

Flood risk to Proposed Scheme

6.2.30 The Environment Agency has provided detailed hydraulic model results from a one-dimensional two-dimensional hydrodynamically linked model. The model uses ISIS for the one-dimensional (channel flow) component of the model and TUFLOW for the two-dimensional (floodplain flow) component. Flood flows at the intersection with the Proposed Scheme are expected to be in the order of 80m^3/s in the 1 in 100 years return period (1% annual probability) flood, which was calculated based on the catchment descriptors at the intersection. The model shows that around 30% of the flow would be conveyed within the channel and the remainder would pass along the floodplain. The highest modelled flood water levels along the viaduct occur in the floodplain to the north of the channel due to inflows from the Fleet Marston Brook immediately upstream of the Proposed Scheme.

6.2.31 The baseline estimates of maximum flood water levels at the crossing are presented in Table 7. The minimum top of rail level within the area of flood risk will be immediately north of flood storage area at 74.8m AOD.

Table 7: River Thame model details (critical 30.25hr storm)

	1% annual probability	1% annual probability including climate change allowance	0.1% annual probability
Peak channel flow	23.1m^3/s	24.1m^3/s	27.7m^3/s
Peak floodplain water level	70.93m AOD	70.97m AOD	71.02m AOD
Peak channel water level	70.83m AOD	70.90m AOD	70.98m AOD

6.2.32 Comparison of the Proposed Scheme with the predicted flood water levels from the hydraulic model results shows that the minimum top of rail level will be at least 3.8m above the predicted 1,000 years return period (0.1% annual probability) flood water level. As a result, the risk of river flooding on the operational portion of the Proposed Scheme will be less than 0.1% (low risk). There are no other elements to the Proposed Scheme that will potentially be at risk of flooding from the River Thame.

6.3 Risk of flooding from surface water

6.3.1 There are areas of flood risk shown on the Environment Agency FMfSW associated with the Stoke Brook and River Thame. In these cases, the extent of flooding is within the extent of flooding from rivers as assessed in Section 6.2 of this report. Since flooding from direct surface water runoff occurs early in any given rainfall event is likely to have receded prior to the onset of any significant flooding from the watercourses. On this basis there is unlikely to be any significant cumulative effect due to combined flooding from direct runoff and from the watercourse that would not already be accounted for in the flood risk from rivers analysis discussed previously. As a result, flood risk from the rivers will be the dominant source of flood risk to the line with additional effects from direct runoff likely to be negligible and therefore not assessed further in this section.

Old Risborough Road

6.3.2 The Old Risborough Road, as shown on Map CT-06-041, G7 (Volume 2, CFA11 Map Book), is shown on the FMfSW to be at risk of shallow (between 100mm and 300mm in depth) flooding from surface water runoff during the 1 in 200 years return period (0.5% annual probability) rainfall event. The road appears to form a channel for rainwater towards the Stoke Brook before discharging downstream of Risborough Road. The only design element that will lie within the area at risk of flooding is Stoke Mandeville south embankment.

6.3.3 The Stoke Mandeville south embankment will be a minimum of 4.2m above existing ground levels through the area at risk of flooding and therefore no less than 3.9m above potential maximum flood levels in the 1 in 200 years return period (0.5% annual probability) rainfall event (no risk).

Sedrup Ditch

6.3.4 Where the route will cross the Sedrup Ditch valley (SWC-CFA11-08) the FMfSW shows a 200m wide area at risk of shallow (between 100mm and 300mm in depth) flooding from surface water runoff during the 1 in 30 years return period (3.3% annual probability) rainfall event or deep (greater than 300mm in depth) flooding from direct runoff during the 1 in 200 years return period (0.5% annual probability) rainfall events, as shown on Map WR-01-014, D6 (Volume 5, Water Resources and Flood Risk Assessment Map Book). Comparison of the 100mm and 300mm FMfSW outlines with ground levels suggests a 1 in 200 years return period (0.5% annual probability) flood level of no more than 78.5m AOD. The design element that will fall within the area at risk of flooding is Aylesbury embankment.

6.3.5 The minimum top of rail level within the area shown to be at risk will be 83.4m AOD and the embankment height through the area will be no less than 4.9m. There will be a freeboard of at least 4.9m for the minimum top of rail level at the Sedrup valley crossing and the 1 in 200 years return period (0.5% annual probability) surface water flood level (no risk).

Hartwell ditches

6.3.6 Where the route will cross the valley of the Hartwell ditches the FMfSW shows scattered areas along the valley and across Aylesbury Vale Golf Club to be at risk of shallow (between 100mm and 300mm in depth) flooding from surface water runoff during both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events as shown on Map WR-01-015, H5-H6 (Volume 5, Water Resources and Flood Risk Assessment Map Book). Design elements that will fall within the area at risk of flooding are the Oxford Road embankment and Footpath SBH/32 overbridge.

6.3.7 The embankments will be a minimum of 2.9m above existing ground level through the area of risk. There will therefore be a freeboard of at least 2.6m between the 1 in 200 years return period (0.5% annual probability) surface water flood level and the minimum top of rail level at the Hartwell valley crossing (no risk).

Fleet Marston and Cranwell ditches

6.3.8 To the north of Fleet Marston Spinney the route will cross areas shown on the FMfSW to be at risk of shallow (between 100m and 300m in depth) flooding from surface water runoff during both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events (SWC-CFA11-15 and SWC-CFA11-16). The areas at risk are associated with two watercourses which flow predominantly in a south-west to north-east direction and form a tributary of the Fleet Marston Brook which they join at Berryfields Farm as shown on Map WR-01-015, D5-E6 (Volume 5, Water Resources and Flood Risk Assessment Map Book). Design elements that will lie within the area at risk of flooding are Bicester Road embankment and Cranwell Farm footbridge.

6.3.9 The Bicester Road embankment will be a minimum of 2m above existing ground levels through the area at risk of flooding and therefore no less than 1.7m above potential maximum flood levels in the 1 in 200 years return period (0.5% annual probability) rainfall event (no risk). The footbridge will be further raised to pass over the Proposed Scheme (no risk).

Cranwell Farm

6.3.10 As the route leaves CFA11, it will cross an area shown on the FMfSW to be at risk of shallow (between 100m and 300m in depth) flooding from surface water runoff during both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events. Although the route has the potential to have an impact on the risk of flooding from this source to receptors in CFA11, elements of the Proposed Scheme that fall within the risk area form part of the Proposed Scheme within CFA12. The potential risk of flooding to the Proposed Scheme from this source is therefore covered in the FRA for CFA12 (Volume 5: Appendix WR-003-012).

6.4 Risk of flooding from groundwater

6.4.1 The BGS dataset indicates that the route will intersect areas of 'high' and 'very high' susceptibility to flooding from groundwater within the local superficial deposits along

the Stoke Brook valley near to Bishopstone and South Aylesbury, at Lower Hartwell within the Thame Valley and around Cranwell and Fleet Marston ditches.

6.4.2 Where the route will be raised above surrounding ground, either on embankment or viaduct, the risk of flooding from groundwater is negligible. The Hartwell and Thame valleys will be crossed on embankment and viaduct respectively and the area at risk near Fleet Marston will also be crossed on embankment. The Stoke Brook area of susceptibility, however, will be crossed in cutting.

Bishopstone

6.4.3 The BGS susceptibility to groundwater flooding maps show an area at risk of groundwater emergence arising from superficial deposits along the valley of the Stoke Brook with an area at risk significantly greater than that shown on the Flood Zone maps or the FMfSW. Design elements that will lie within the area at risk are Aylesbury south cutting and Aylesbury embankment.

6.4.4 The BGS dataset describes the superficial stratum as an unlithified polymict deposit (mass movement deposit), comprising gravel, sand and clay. Such deposits are usually formed by hillwash or soil creep. The band is approximately 1km long and up to 160m wide and runs adjacent and parallel to the alluvial deposits of the Stoke Brook with the combined strata being classified as a secondary undifferentiated aquifer in the BGS aquifer designation dataset. Emergent groundwater was observed during the site familiarisation visit to the Stoke Brook in December 2012. The bedrock is the Gault mudstone formation of the Selborne Group, which is unproductive.

6.4.5 The cutting will extend through the superficial deposits and into the Gault mudstone beneath and groundwater will potentially emerge from the cutting walls at the interface between the strata. The route will be 6m below ground levels at the southern extent of the area at risk.

6.5 Risk of flooding from drainage systems

6.5.1 The route will not pass through any urban areas for the full extent within CFA11. There will consequently be no significant risk of flooding from urban drainage within the study area.

6.6 Risk of flooding from artificial sources

Tring Reservoirs

6.6.1 At the crossing of the River Thame (SWC-CFA11-13), the route will intersect an area shown to be at risk on the Environment Agency RIM in the event of failure of the Wilstone, Marsworth and Startops End reservoirs (collectively the Tring reservoirs) as shown on Map WR-01-015, F5 (Volume 5, Water Resources and Flood Risk Assessment Map Book). The modelled extent shows the largest area that might be flooded if each reservoir were to fail and fully release all of the water that it holds, which is shown for all three reservoirs, to be similar in extent to the floodplain (river flooding) of the River Thame with water conveyed into the Thame Valley via the Wilstone, Tring and Long Marston Brooks. The Thame Valley viaduct design element will lie within the area at risk of flooding.

6.6.2 The Environment Agency RIM only displays the residual risk of failure of artificial water bodies with a capacity above 25,000m^3, which are covered under the Reservoirs Act 1975[12] (as amended by the Flood and Water Management Act 2010[13]). This requires water companies to maintain their reservoirs such that the annual probability of a breach of the reservoir is 1 in 50,000. Although there is a potential impact on the residual risk of flooding from the reservoir the likelihood of such flooding occurring is extremely low.

6.6.3 Comparison of the RIM with LiDAR ground level information suggests a maximum flood level 71m AOD since the outlines lie within the 71m AOD contour. The minimum top of rail level at the crossing will be 74.8m AOD and there will therefore be a freeboard of over 3.8m above the predicted maximum water level from this source.

6.6.4 In the event of a reservoir breach, flood flows would be expected to be rapid with a high energy, resulting in an elevated risk of erosion and scour. The source of flooding, which lies within the Thame catchment, is more than 16km upstream of the Proposed Scheme and flood flow energies are likely to be reduced by the time floodwaters reach the Proposed Scheme.

6.6.5 There will not be a significant risk of flooding to the Proposed Scheme from failure of the Tring Reservoirs.

6.7 Summary of baseline flood risk

Table 8: Summary of baseline flood risk for all sources of flooding in CFA11

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
River	Stoke Brook	Very high Flood Zone 3b	Stoke Mandeville south embankment	Top of rail level will be >1m above 1,000 years return period water level.
			Footpath ELL/20 overbridge	Footpath level will be >1m above 1,000 years return period water level.
			Footpath SMA/9 accommodation overbridge	Footpath will be raised above existing level - risk will be reduced
			Stoke Mandeville Bypass overbridge	Road level will be >1m above 1,000 years return period water level.
			Princes Risborough to Aylesbury Line overbridge	Embankment level will be >1m above 1,000 years return period water level.
River	Sedrup Ditch	Very high Flood Zone 3b	Aylesbury embankment	Top of rail level will be >1m above 1,000 years return period water level.

[12] *Reservoirs Act 1975* (c.23). London, Her Majesty's Stationery Office.
[13] *Flood and Water Management Act 2010* (c.29). London, Her Majesty's Stationery Office.

Source of flooding	Location of flooding source	Flood risk category	Elements at risk	Assessment of risk
River	Hartwell ditches	Very high Flood Zone 3b	Oxford Road embankment	Top of rail level will be >1m above 1,000 years return period water level.
		Medium Flood Zone 2	Footpath SBH/32 overbridge	Embankments will be raised above floodplain.
River	River Thame	Very high Flood Zone 3b	Thame Valley viaduct	Top of rail level will be >1m above 1,000 years return period water level.
Surface water	Old Risborough Road	Low 200 years FMfSW <0.3m	Stoke Mandeville south embankment	Top of rail level will be >1m above ground level.
Surface water	Sedrup valley	Medium 200 years FMfSW >0.3m 30 years FMfSW <0.3m	Aylesbury embankment	Top of rail level will be >1m above estimated flood water level.
Surface water	Hartwell valley	High 30 years FMfSW >0.3m	Oxford Road embankment	Top of rail level will be >1m above estimated flood water level.
		Low 200 years FMfSW <0.3m	Footpath SBH/32 overbridge	Embankments will be raised above ground level.
Surface water	Fleet Marston and Cranwell ditches	Low 200 years FMfSW <0.3m	Bicester Road	Top of rail level will be >1m above estimated flood water level.
			Cranwell Farm footbridge	Embankments will be raised above ground level.
Groundwater	Bishopstone	High Very high Susceptibility	Aylesbury south cutting	Emergent groundwater will be collected in surface water drainage system and discharged to local watercourses. Top of rail level will be below ground level – at risk.
Artificial sources	Embankment failure at Tring Reservoirs	Low Within inundation mapping extent	Thame Valley viaduct	Top of rail level will be >1m above estimated flood water level.

7 Flood risk management measures

7.1 Risk of flooding from rivers

7.1.1 The route will be raised above crossings of floodplains (river flooding) such that the risk of flooding from this source is less than 0.1%. Consequently no specific management measures are required.

7.1.2 Replacement floodplain storage will be provided upstream of the Proposed Scheme for all losses in floodplain storage including viaduct piers, embankments and all associated development. This applies to the Stoke Brook and River Thame viaduct.

7.1.3 Surface flows into the channels of the Sedrup and Hartwell ditches will be collected and conveyed in culverts with sufficient capacity to convey the 1 in 100 years (1% annual probability) flows including a 30% allowance for climate change.

7.2 Risk of flooding from surface water

7.2.1 The FMfSW shows the extent of flooding due to rainfall that would occur prior to collection of water into streams or designated drainage infrastructure. By collecting the flows from the dry valley into an adequately designed land drainage system the Proposed Scheme will effectively remove the risk of surface water flooding from the point at which the flow is intercepted.

7.2.2 Measures to manage the risk of flooding from surface water runoff include:

- provision of replacement floodplain storage and surface water attenuation facilities to restrict peak surface water runoff rates to existing greenfield rates;
- culverts have been designed with adequate capacity to convey the 1 in 100 years (1% annual probability) flow including an allowance for climate change; and
- design of culverts with internal 600mm freeboard and 300mm allowance for siltation to minimise the chances of blockage or future capacity restrictions;

7.2.3 There are no locations where the top of rail level of the Proposed Scheme will be less than 1m above ground level in an area shown to be at risk of flooding from surface water runoff. No further management measures will be required.

7.3 Risk of flooding from groundwater

7.3.1 There is potential for surface ponding arising from high groundwater levels within the cutting along the Stoke Brook valley near Bishopstone. Emergent groundwater will be collected into the track drainage system for the Proposed Scheme.

7.4 Risk of flooding from drainage systems

7.4.1 There will be no risk of flooding from drainage systems to the Proposed Scheme, nor any anticipated effects on the risks of flooding from drainage systems within the study area arising from the Proposed Scheme. Therefore, no specific management measures will be required.

7.5 Risk of flooding from artificial sources

7.5.1 There are no instances where the Proposed Scheme will be at significant risk of flooding from artificial sources and consequently no specific management measures will be required.

7.5.2 Potential flood water levels and extent arising as a result of breach of the Tring Reservoirs will be reduced relative to the design river flood in the River Thame and therefore replacement floodplain storage provided to mitigate the potential effects of the viaduct will serve to offset any potential effects on the severity of flooding from this source. Due to the extremely low probability of such flooding occurring and the likely low significance of any impacts arising from the Proposed Scheme it is not considered necessary to provide specific mitigation for this scenario.

8 Post-development flood risk assessment

8.1 Local receptors

8.1.1 In addition to the risk of flooding that exists to the Proposed Scheme, there is potential for the Proposed Scheme to affect the risk of flooding to third party receptors by altering flow mechanisms across the range of flood sources. All local receptors with a potential flood risk are identified in Section 5.2 of this report. For the Proposed Scheme to have an impact on a given receptor, the identified pathway for that receptor must be shared by both the subject receptor and the Proposed Scheme with the result that a number of cases can be excluded immediately. Table 9 summarises the shared pathways between the Proposed Scheme and each receptor and identifies cases where no shared pathway exists.

Table 9: Shared flood risk pathways in CFA11

Local receptor	Vulnerability classification as per the NPPF	Pathway	Shared pathway between Proposed Scheme and receptor
Triangle Business Park	Less vulnerable	Surface water 30 years - deep	No shared pathway (existing railway culvert between Proposed Scheme and receptor).
Stoke Grove Farm	More vulnerable	Surface water 30 years - deep	Stoke Mandeville south embankment will be approximately 550m downstream.
Stoke House	More vulnerable	Surface water 30 years - deep	No shared pathway (flow concentrated through millpond between Proposed Scheme and receptor).
Bucks Goat Centre	Less vulnerable	Surface water 200 years - shallow	Stoke Mandeville south embankment will be approximately 250m downstream.
Old Risborough Road houses	More vulnerable	Surface water 200 years - shallow	Stoke Mandeville south embankment will be approximately 25m downstream.
The Paddock	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep	Stoke Mandeville south embankment will be approximately 200m upstream.
Stoke Mandeville village	More vulnerable	Surface water 30 years - deep Highway drainage	No shared pathway.
Ayres Yard	Less vulnerable	Surface water 30 years - shallow	No shared pathway.

Local receptor	Vulnerability classification as per the NPPF	Pathway	Shared pathway between Proposed Scheme and receptor
Brook Farm	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep	Stoke Mandeville south embankment will be approximately 800m upstream. Stoke Mandeville Bypass overbridge will be approximately 1km downstream.
Moat Farm	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep Groundwater - very high	Stoke Mandeville south embankment will be approximately 1.1km upstream Stoke Mandeville bypass overbridge will be approximately 900m downstream
Hall End	More vulnerable	Surface water 30 years - shallow	No shared pathway.
Princes Risborough to Aylesbury Line	Less vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep Groundwater - very high	Line will be realigned across the Proposed Scheme.
Aylesbury Town	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - shallow Groundwater - very high Bear Brook flood storage reservoir failure	Groundwater only (river flooding zones, surface water areas and flood storage reservoir are within Bear Brook valley). Aylesbury south cutting will intersect area at risk of groundwater flooding.
Standalls Farm	More vulnerable	Surface water 30 years - shallow	No shared pathway.
Sedrup Lane residential area	More vulnerable	Surface water 30 years - shallow	Aylesbury embankment will be approximately 900m downstream.
Sedrup Farm	More vulnerable	Surface water 30 years - shallow	No shared pathway.
Calley Farm	More vulnerable	Surface water 200 years - shallow	No shared pathway.
Hartwell Depot	Less vulnerable	Groundwater - high	No shared pathway.
Meadoway residential area	More vulnerable	Surface water 30 years - shallow	No shared pathway.
Hartwell Cottage	More vulnerable	Groundwater - high	No shared pathway.

Local receptor	Vulnerability classification as per the NPPF	Pathway	Shared pathway between Proposed Scheme and receptor
Hartwell House and parkland	More vulnerable	Surface water 30 years - shallow Groundwater - very high	Oxford Road embankment will be approximately 900m downstream.
Aylesbury Park Golf Club	Less vulnerable	River flooding Flood Zone 2 Surface water 30 years - shallow Groundwater - very high	Oxford Road embankment and Footpath SBH/32 overbridge will be at this location.
Upper Hartwell village	More vulnerable	Surface water 200 years - shallow	Oxford Road embankment will be approximately 900m downstream.
Fairford Leys village	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - shallow Groundwater - very high Stocklake flood storage reservoir failure Bear Brook flood storage reservoir failure	River flooding zones, surface water areas and Flood Storage Reservoir risk areas are within Bear Brook valley- no shared pathway Proposed Scheme is above ground through shared areas of groundwater flood risk.
Lower Hartwell village	More vulnerable	Surface water 30 years - deep Groundwater - very high	Oxford Road embankments will be approximately. 300m downstream.
Aylesbury (west)	More vulnerable	River flooding Flood Zone 2	No shared pathway.
Fairford Leys flood storage area	Water compatible	River flooding Flood Zone 3 Surface water 30 years - shallow Tring reservoirs failure	Thame Valley viaduct will be at this location.
Aylesbury Sewage Treatment Works	Less vulnerable	River flooding Flood Zone 2 Groundwater - very high	No shared pathway.
Putlowes	More vulnerable	Surface water 30 years - shallow	Thame Valley viaduct will be approximately 450m downstream.
Putlowes Drive residential area	More vulnerable	Surface water 200 years - shallow	No shared pathway.
Berryfields Farm	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep	No shared pathway.
Old Rectory Cottage	More vulnerable	Groundwater - very high	No (existing roadway culvert between Proposed Scheme and receptor).

Local receptor	Vulnerability classification as per the NPPF	Pathway	Shared pathway between Proposed Scheme and receptor
Hunters Farm industrial estate	Less vulnerable	Surface water 30 years - shallow and 200 years - deep Groundwater - very high	Bicester Road overbridge and Bicester Road embankment (CFA12) will be approximately 550m upstream.
Upper Cranwell Farm	More vulnerable	Surface water 200 years - shallow	Bicester Road embankment and Cranwell Farm Footbridge will be approximately 700m downstream.
Fleet Marston Farm	More vulnerable	Surface water 30 years - shallow -and 200 years - deep	Bicester Road overbridge and Bicester Road embankment (CFA12) will be approximately 500m upstream.

8.1.2 There is also the potential for the Proposed Scheme to change the baseline risk of flooding described in Section 6 of this report. Though designed such that the probability of the Proposed Scheme flooding in any given year is less than 1 in 1,000, any change to the baseline risk of flooding could impact on the assessment of flood risk to the Proposed Scheme. All cases of flood risk discussed in Section 6 of this report are therefore reconsidered regardless of the presence or otherwise of third party local receptors.

8.2 Impact on risk of flooding from rivers

Stoke Brook

Description

8.2.1 The Stoke Brook is a tributary of the River Thame and flows approximately parallel to the route past Stoke Mandeville. The route will cross the watercourse and its mill stream at five locations (SWC-CFA11-02 to SWC-CFA11-06). The Proposed Scheme and associated works have the potential to affect the floodplain between Nash Lee Orchard and Oat Close in Aylesbury, a distance of approximately 3.7km. The land use in the floodplain is predominantly agricultural, but also includes fish ponds and buildings at Moat Farm, Brook Farm and the site of the former St Mary's Church.

8.2.2 The vertical alignment for this section will be embankment and grade level. The Stoke Brook will also be affected by Public Rights of Way (PRoW) and road diversions at Nash Lee Orchard, Whitethorn Farm and Stoke Mandeville Bypass which will all be on embankment in the floodplain. In addition, the Princes Risborough to Aylesbury Line will be permanently realigned with consequent works to the existing floodplain crossing.

8.2.3 Maintenance sidings and associated access works are currently proposed alongside the line of route at the south of CFA11. Ground raising will be undertaken along both sides of the route embankment with the sidings themselves on the eastern side and

access tracks on both sides. The western access track will cross the natural channel and floodplain of the Stoke Brook.

8.2.4 This section of the route will require major river channel diversions and floodplain reconfiguration with potential significant impacts on the risk of and from flooding in the immediate vicinity of the Stoke Brook and potentially downstream at Aylesbury.

Local receptors and land use

8.2.5 Formal receptors within the 1km buffer extent that could be affected by the Proposed Scheme near the Stoke Brook are The Paddock, Brook Farm, Moat Farm and the Princes Risborough to Aylesbury Line. The Princes Risborough to Aylesbury Line embankment will be permanently realigned as part of the Proposed Scheme.

8.2.6 The land use within the floodplain in the vicinity of the Proposed Scheme is largely made up of arable farm land and pasture with the exception of the three residential properties. Two public roads cross the floodplain in the area: Risborough Road and Marsh Way. There is a historic burial ground at the site of the former St Mary's church which lies within the floodplain upstream of Risborough Road.

Potential effects

8.2.7 There are several key design elements that have the potential to affect flood flows at Lower Thorpe. These are the Stoke Mandeville south embankment, including watercourse diversions and culverts, the maintenance sidings, Footpath ELL/20 overbridge, Footpath SMA/9 accommodation overbridge, Stoke Mandeville bypass overbridge and Princes Risborough to Aylesbury Line overbridge.

8.2.8 The route will initially cross the natural channel of the Stoke Brook on the boundary of CFA10 with CFA11. At the same location, the Proposed Scheme will be crossed by the Footpath ELL/20 overbridge and the northern approach embankment will cross the watercourse and floodplain just upstream of the embankment of the Proposed Scheme. The Stoke Brook will be conveyed beneath the two embankments by culverts with a short channel diversion in between. Both the culverts and the channel diversion will be sized appropriately to convey the full 1 in 100 years return period (1% annual probability) flood flow including an allowance for climate change and allowances for siltation and blockage. A tributary from Nash Lee joins the Stoke Brook at this location and will be diverted along the western side of the Proposed Scheme to the culvert outlet. Flooding along this section of the Stoke Brook is to the south of the channel, which continues for around 300m parallel to the Proposed Scheme. There will consequently be limited displacement of floodwaters due to the Proposed Scheme at this crossing.

8.2.9 Approximately 200m downstream of the Proposed Scheme crossing at Nash Lee Orchard the channel bifurcates and the natural channel of the Stoke Brook leaves the larger artificial channel, which conveys water to the millpond at Stoke House, via a small lateral weir. Both watercourses then swing northwards and the route will again cross both watercourses. Due to the acute angle between the Stoke Brook and the Proposed Scheme embankment, as well as the width of the proposed embankment footprint, the Proposed Scheme will result in the loss of around 150m of the mill stream channel, approximately 500m of the natural channel and a plan area of

approximately 16,500m^2 of floodplain. The mill stream will be conveyed beneath the Proposed Scheme in a culvert perpendicular to the embankment with a new channel created along the eastern side of the Proposed Scheme. The natural channel will be diverted along the western side of the Proposed Scheme to maintain continuity with the floodplain and will cross the embankment via a perpendicular culvert at the downstream extent of the obstructed channel to outfall to the continuing watercourse on the eastern side of the Proposed Scheme. Rainfall on the eastern side of the Proposed Scheme that would have discharged into the natural channel will be collected in a new ditch to outfall to the Stoke Brook downstream of the new culvert. All elements will be sized appropriately to convey the full 1 in 100 years return period (1% annual probability) flood flow including an allowance for climate change, siltation and blockage.

8.2.10 Due to the complexity of the flood risk from the Stoke Brook in this area and the lack of previously established hydraulic model information, the impact of the Proposed Scheme upstream of Risborough Road is assessed using the results of the detailed hydraulic modelling used to assess the baseline flood risk. This modelling extends beyond the current limits of the flood zones and therefore also covers surface water effects in the immediate vicinity. For more detail on the hydraulic modelling refer to Volume 5, Appendix WR-004-003.

Assessment of effects

8.2.11 The hydraulic modelling carried out for this FRA showed that, at the majority of locations, the extents of the return period flood events investigated for the Stoke Brook are confined to the channel under current conditions. Whilst significant channel works are required under the Proposed Scheme, design standards are such that the impact on the risk of flooding, up to and including the 1 in 100 years return period (1% annual probability) event including an allowance for climate change (the design event), will be negligible. All channel diversions and culverts will be designed with sufficient capacity to convey the design event without out-of-bank flooding or surcharge, including additional allowances for siltation and culvert blockage.

8.2.12 The only location where the footprint of the Proposed Scheme extends into an area of modelled floodplain is between the two channels, to the south-east of St Mary's Church and, in the 1 in 1,000 years return period (0.1% annual probability) event only, an area of the field to the north of St Mary's Church. An area has been set aside within the construction boundary for the Proposed Scheme along the southern extent of the floodplain to provide replacement floodplain storage. The replacement floodplain storage will act in combination with the network of diverted watercourses to offset losses in floodplain storage and ensure that there is no increase in the risk of flooding from the Stoke Brook in the area.

8.2.13 The capacity of the existing channel is greater than the 1 in 1,000 years return period flood flow at the majority of locations and the existing channel dimensions will be considered in designing the geometry of the diverted watercourses. The design includes four culverts and three diversions and will be designed with due consideration for existing channel capacities.

8.2.14 The detailed design of the Proposed Scheme will incorporate the recommendations of the hydraulic modelling report and therefore no significant effect on the risk of flooding to third party receptors is expected.

8.2.15 Some 1.5km downstream of the Proposed Scheme crossing of the Stoke Brook, the Stoke Brook and its floodplain will be crossed by the re-aligned Princes Risborough to Aylesbury Line and the Stoke Mandeville Bypass overbridge diversion. The realigned railway will not interfere with existing flow conditions for the Stoke Brook and its floodplain. The proposed Risborough Road diversion, however, will create an additional obstruction to floodplain flow relative to the baseline case. In addition, the Footpath SMA/9 accommodation overbridge northern approach embankment will extend to the western bank of the Stoke Brook between the existing Risborough Road and Marsh Lane crossings. This will obstruct floodplain flows along the western floodplain potentially affecting the risk of flooding in the area.

8.2.16 Although the model was prepared to assess the mechanisms of flooding upstream of Risborough Road the downstream boundary of the model is at Moat Farm somewhat downstream of Risborough Road. This downstream section of the model has not been interrogated or refined but can be used as a guide and to supplement the flood zone outlines. The model results suggest that, based on the LiDAR information, there is no out-of-bank flooding in the 1 in 100 years return period (1% annual probability) flood event including an allowance for climate change. There are no hydraulic structures in this section of the model and backing up may occur behind the Marsh Lane culvert depending on capacity. Nevertheless, the model suggests that the Stoke Brook channel downstream of Risborough Road has sufficient capacity to convey the 1 in 100 years return period (1% annual probability) flood flow including an allowance for climate change and consequently raised construction within the floodplain will not cause an obstruction to flood flows provided culverts have been designed with equal capacity to the channel. Raised structures within the floodplain would displace floodwaters due to occupation of floodplain storage.

8.2.17 The Footpath SMA/9 accommodation overbridge does not cross the channel of the Stoke Brook and will therefore not have any significant dynamic effect on the risk of flooding. The overbridge is approximately 200m upstream of the existing Marsh Lane crossing of the Stoke Brook and the capacity of the culvert is unknown. Flooding may result in the area of the overbridge due to backing up behind the Marsh Lane culvert and there is therefore a potential impact of the overbridge embankment on flood water levels due to displacement of floodplain storage. An area has been set aside within the boundary of the Proposed Scheme to provide replacement floodplain storage to offset this impact and the overall effect of the overbridge on the risk of flooding is expected to be negligible.

8.2.18 The Stoke Mandeville Bypass overbridge crosses the floodplain of the Stoke Brook downstream of the model boundary. There is therefore no modelled information in this area, however, according to the available LiDAR data and the capacity of the channel relative to both upstream and downstream sections (where model data suggests that there is no out-of-bank flooding) is similar to upstream. The culvert below the overbridge will be designed with sufficient capacity to convey the 1 in 100

years return period (1% annual probability) flood flow including an allowance for climate change and allowances for siltation and blockage. Any backing up behind the existing Princes Risborough to Aylesbury Line embankment may cause out-of-bank flooding in the vicinity of the proposed road embankment, however, an area of replacement floodplain storage is included in the design to allow for any floodplain displacement and the overall effect of the overbridge on the risk of flooding is therefore expected to be negligible.

Sedrup Ditch

Description

8.2.19 The route will cross the Sedrup Ditch on embankment (SWC-CFA11-08) with a culvert proposed to carry the Sedrup Ditch beneath the embankment. The culvert will be sized appropriately to convey the full 1 in 100 years return period (1% annual probability) flood flow including an allowance for climate change and allowances for siltation and blockage.

8.2.20 The flood zones of the Sedrup Ditch are restricted to the width of the channel, based on the hydraulic modelling of the Upper Thame catchment as discussed in Section 6.2 of this report. The FMfSW, however, shows extensive areas of potential flooding from surface water runoff along the Sedrup valley.

Local receptors and land use

8.2.21 Formal receptors within the 1km buffer extent that could be affected by the Proposed Scheme around Sedrup are Sedrup Farm and residential properties on Sedrup Lane including Well Cottage. Both receptors are approximately 950m upstream and lie within the extents of the FMfSW. The land use in the floodplain immediately upstream of the crossing is young woodland and arable land.

Assessment of effects

8.2.22 The route will cross the Sedrup Ditch on embankment with the watercourse conveyed beneath the Proposed Scheme in a culvert. The hydraulic model shows the full flow in the Sedrup Ditch to be contained within channel up to and including the 1 in 1,000 years return period (0.1% annual probability) flow. The culvert will be sized appropriately to convey the full 1 in 100 years return period (1% annual probability) flood flow including an allowance for climate change, siltation and blockage and there will consequently be no impact on the risk of river flooding in the Sedrup Ditch.

8.2.23 The formal receptors within the Sedrup valley are located nearly 1km upstream of the Proposed Scheme and the risk of flooding will not be affected. The Proposed Scheme will potentially result in a reduced risk of flooding from surface water sources downstream of the Proposed Scheme, on land belonging to the Ernest Cook Trust (Calley Farm), due to collection of water into the formalised channel.

Hartwell ditches

Description

8.2.24 The Hartwell ditches are tributaries of the Bear Brook, in turn part of the River Thame catchment. Where the route will cross the watercourse there are two channels and a

tributary as well as a second tributary that flows south parallel to the Proposed Scheme between the two main channels and outfalls to the southern channel (SWC-CFA11-09 to SWC-CFA11-11). The watercourses form part of the Aylesbury Park Golf Club and may have been historically diverted.

8.2.25 The route will cross the Hartwell ditches on embankment with two culverts proposed to carry the watercourses beneath the embankment. The Lower Hartwell PRoW overbridge coincides with the southern channel of the Hartwell ditches with watercourse diversions and culverts required to reinstate the watercourse away from the overbridge approach embankments. All elements will be sized appropriately to convey the full 1 in 100 years return period (1% annual probability) flood flow, including an allowance for climate change, siltation and blockage.

8.2.26 Flood Zone 3 of the Hartwell ditches is restricted to the width of the channels, based on the hydraulic modelling of the Upper Thame catchment as discussed in Section 6.2 of this report. Flood Zone 2 has been expanded to include areas known to have flooded historically although this may have arisen from alternative sources such as high groundwater levels. Additionally, the FMfSW shows extensive areas of potential flooding from direct runoff along the Hartwell valley.

Local receptors and land use

8.2.27 Formal receptors within the 1km buffer extent that could be affected by the Proposed Scheme around Hartwell are Hartwell House Hotel and Park, Upper Hartwell, Lower Hartwell and the Aylesbury Park Golf Club. Lower and Upper Hartwell are 350m and 850m upstream of the Proposed Scheme respectively. Hartwell House is approximately 400m upstream of the Proposed Scheme while the parkland is immediately upstream. Aylesbury Park Golf Club is approximately 300m downstream of the Proposed Scheme with the course itself extending on both sides of the Proposed Scheme. The land use in the floodplain in the vicinity of the Proposed Scheme is the leisure facilities of Aylesbury Park Golf Club.

Assessment of effects

8.2.28 The route will cross the Hartwell ditches on embankment with the watercourses conveyed beneath the Proposed Scheme in culverts and/or diverted around the Proposed Scheme. Alterations are proposed to the watercourse, however, since the upper Thame catchment hydraulic model shows the full flow in the ditches to be contained within channel up to and including the 1 in 1,000 years return period (0.1% annual probability) flow. The culverts will be sized appropriately to convey the full 1 in 100 years return period (1% annual probability) flood flow, including an allowance for climate change, siltation and blockage and there will consequently be no impact on the risk of flooding in the Hartwell ditches.

8.2.29 The formal receptors upstream of the Proposed Scheme are located sufficiently distant that the risk of flooding will not be affected. The Proposed Scheme will potentially result in a reduced risk of flooding from surface water downstream of the Proposed Scheme, i.e. at Aylesbury Park Golf Club, due to collection of water into formalised channels.

River Thame

Description

8.2.30 The route will cross the River Thame (SWC-CFA11-13) and floodplain to the west of Aylesbury with the floodplain spanned on viaduct. The route will cross the river channel and floodplain perpendicular to the flow direction. The viaduct crossing will be 965m in length and will also pass across the Fairford Leys flood storage area.

Local receptors and land use

8.2.31 One formal receptor lies within the 1km buffer extent that could be affected by the Proposed Scheme along the River Thame Valley. This is Putlowes (a farm and residential property) approximately 400m upstream of the Proposed Scheme along the Fleet Marston Brook.

8.2.32 The land use in the floodplain in the vicinity of the Proposed Scheme is arable farm land and pasture.

Potential effects

8.2.33 The single design element that has the potential to affect flood flows in the River Thame is the Thame Valley viaduct. The viaduct will be supported on 47 double piers located at 20m centres. Since viaduct piers are proposed within the floodplain flow area the Proposed Scheme will potentially obstruct floodplain flows which could lead to increased water levels upstream of the Proposed Scheme. Each viaduct pier will additionally displace flood water, leading to further potential increases in surrounding flood water levels.

Assessment of effects

8.2.34 The baseline estimates of maximum flood water levels at the crossing are presented in Table 10. The minimum top of rail level will be 74.8m AOD and the viaduct deck (rail to soffit) will be 2m deep, resulting in a minimum soffit level of 72.8m AOD. The viaduct deck will clear the floodplain with a freeboard to the 1 in 1,000 years return period (0.1% annual probability) flood water level.

8.2.35 The viaduct is designed to span the full extent of the 1 in 1,000 years return period (0.1% annual probability) floodplain since the structure will be 965m in length. It will, however, be necessary for piers to be constructed within the floodplain. The velocity grid provided by the Environment Agency from the Bear Brook and Upper Thame Flood Risk Mapping Study indicates that peak velocities within the floodplain at the point of crossing are 0.2m/s between the flood storage area and the River Thame with flow velocities lower within the storage area itself and on the right (northern) bank of the River Thame. In these areas, flow velocities are sufficiently low that the impact of piers within the floodplain on flow patterns will be negligible. There are two identifiable flow pathways where viaduct piers would potentially have an impact due to increased flood flow velocities. These are the channel of the River Thame (peak flow velocity of 1m/s across a width of approximately 30m) and along the north western boundary of the flood storage area (peak flow velocity of 0.5m/s across a width of approximately 40m).

8.2.36 The River Thame viaduct crossing will be constructed approximately 4.5m above the floodplain level, supported on fixed abutments and piers at 20m centres. There will be approximately two piers in the area of high velocity by the flood storage area and one pier within the channel of the River Thame. These piers will impact flood water levels through obstruction of flood flow potentially causing increased flood water levels upstream of the crossing. The scale of the obstruction relative to the extent of flooding at higher return periods is small. As a result, the impact of the two piers adjacent to the flood storage area will be relatively low.

8.2.37 In order to quantify the general effect (afflux) of the Thame Valley viaduct, a simple model of the river network was compiled in InfoWorks RS 13.5.3. The Environment Agency ISIS one-dimensional base model, from downstream of the existing railway line to approximately 500m downstream of the viaduct was imported, including the lower sections of the Bear Brook and Fleet Marston Brook. The cross sections were extended into the floodplain using LiDAR data. Stage-time hydrographs were extracted from the Environment Agency model to form the model boundaries. Simulations were run for the baseline case and a proposed case represented by 20 spans at 20m centres with 2.5m wide piers centred within the floodplain. A secondary simulation was run with a 5 span viaduct to verify that the model boundaries were sufficiently distant from the structure to avoid influencing the calculated afflux.

Table 10: Estimated flood water levels in the River Thame

	1% annual probability	**1% annual probability including climate change allowance**	**0.1% annual probability**
Baseline	70.78m AOD	70.84m AOD	70.92m AOD
Future	70.78m AOD	70.85m AOD	70.92m AOD
Maximum afflux	1mm	2mm	2mm
Maximum influence	Fleet Marston Ditch		

8.2.38 The model showed that the viaduct will not create a significant afflux with increases in modelled flood levels of up to 2mm calculated immediately upstream of the structure. Such increases in water levels are within the uncertainty tolerance of the hydraulic modelling and are therefore negligible. Consequently, the impact on the risk of flooding arising from the River Thame as a result of the viaduct will be negligible. It is noted that, due to the one-dimensional representation of flood flows, localised effects within the areas of high velocity will not have been accounted for in the model. In the scale of the overall flooding, however, these are unlikely to have any effect on the overall afflux observed.

8.2.39 Regardless of the impact of the viaduct piers on the dynamic characteristics of the floodplain, the built volume of the piers within the floodplain will cause displacement of flood water through the removal of floodplain storage. There will be 47 double piers located within the River Thame floodplain each with a combined footprint of approximately 12.5m^2. Of these piers, 13 will be located within the flood storage area, where water depths are up to 1.4m, resulting in a total volume of displaced floodwater

of approximately 228m^3. Excluding the flood storage area, the maximum depth of floodwater along the crossing extent is approximately 700mm, corresponding to a total volume of 298m^3. The combined potential maximum displaced volume will therefore be 526m^3. Replacement floodplain storage has been included in the Proposed Scheme to offset the loss of floodplain.

Summary of effects

8.2.40 The hydraulic modelling and afflux calculations show that the Proposed Scheme will result in a negligible impact on the risk of flooding in the immediate vicinity of the viaduct. Floodwater displacement due to the viaduct piers and abutments will occur.

8.2.41 The single identified receptor within the River Thame floodplain, Putlowes, will not experience any adverse effect on the risk of flooding from the River Thame or Fleet Marston Brook as a result of the Proposed Scheme. There may be small localised effects on the severity of flooding immediately surrounding the viaduct on land belonging to Waddon Hill Farm on the south side and Putlowes Farm on the north side of the watercourse.

8.3 Impact on risk of flooding from surface water

8.3.1 The potential impact on the risk of flooding from surface water runoff within the Stoke Brook valley, Sedrup valley and Hartwell valley are closely related to the impacts on the risk of flooding from watercourses and are therefore considered alongside river flooding in Section 8.2 of this report.

Old Risborough Road

8.3.2 The Old Risborough Road is shown on the FMfSW to be at risk of shallow (between 100m and 300m in depth) flooding from surface water runoff during the 1 in 200 years return period (0.5% annual probability) rainfall event. The road appears to form a channel for rainwater towards the Stoke Brook, discharging downstream of Risborough Road. The Stoke Mandeville south embankment will intercept flows towards the Stoke Brook. Surface water, however, will be collected into land drainage along the western side of the Proposed Scheme and conveyed beneath the Stoke Mandeville south embankment in a culvert near to the current location of Whitethorn Farm. All land drainage elements will be designed with sufficient capacity to convey the 1 in 100 years return period (1% annual probability) surface water flood event including an allowance for climate change, siltation and blockage.

8.3.3 Consequently, there will be no significant impact on the risk of flooding to properties on Old Risborough Road or the Bucks Goat Centre. Balancing ponds are proposed to avoid reducing downstream conveyance times and there will consequently be no impact on the risk of flooding to The Paddocks or the risk of flooding from the Stoke Brook downstream.

Thame Valley

8.3.4 The FMfSW shows areas of the River Thame floodplain to be at risk of shallow (between 100mm and 300mm in depth) flooding from surface water runoff during both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events. The extents of flooding shown are within the floodplain of

the watercourse and, since flooding from surface water runoff occurs early in any given rainfall event, are likely to have receded prior to the onset of any significant flooding from the watercourse. On this basis, there is unlikely to be any significant cumulative effect due to combined flooding from surface water runoff and from the watercourse that is not already accounted for in the river flooding analysis of the River Thame used to assess the baseline case and the likely effect arising from the Proposed Scheme. Consequently, there will be no increase in the severity of the effect of the Proposed Scheme on the risk of flooding within the Thame Valley and any mitigation proposed to offset the minor effects on the severity of river flooding discussed previously will equally serve to counteract the similar effects that will be expected on the risk of surface water flooding along the valley. Consequently Putlowes will not experience any adverse effect on the risk of flooding from surface water runoff in the Thame Valley as a result of the Proposed Scheme.

Fleet Marston and Cranwell ditches

8.3.5 The two watercourses north of Fleet Marston Spinney will be intercepted by the Proposed Scheme. There are areas of shallow flooding (between 100m and 300m in depth) from surface water runoff shown on the FMfSW during both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events. The watercourses and associated valleys flow predominantly to the north-east, forming a tributary of the Fleet Marston Brook, which they join at Berryfields Farm.

8.3.6 The southern watercourse will be diverted along the western side of the Proposed Scheme, via a culvert beneath the embankments of the Cranwell Farm footbridge, to join the northern watercourse. The combined watercourses will then be conveyed beneath the Proposed Scheme in an 1800mm culvert. All culvert and diversion elements are designed with sufficient capacity to convey the 1 in 100 years return period (1% annual probability) surface water flood event including an allowance for climate change, siltation and blockage.

8.3.7 Consequently, there will be no significant impact on the risk of flooding to Upper Cranwell Farm. Any potential reductions in floodwater conveyance time within the vicinity of the Proposed Scheme are likely to be negligible and consequently will not significantly affect the risk of flooding arising from downstream sources such as the Fleet Marston Brook and tributaries.

Cranwell Farm

8.3.8 As the Proposed Scheme leaves CFA11 it will cross an area shown on the FMfSW to be at risk of shallow (between 100m and 300m in depth) flooding from surface water runoff during both the 1 in 30 years and 1 in 200 years return period (3.3% and 0.5% annual probability) rainfall events. Elements of the Proposed Scheme that fall within the risk area form part of the Proposed Scheme within CFA12. The Proposed Scheme, however, has the potential to have an impact on the risk of flooding from this source to receptors in CFA11.

8.3.9 At this location the route will be on low embankment and therefore surface water flood flows will be disrupted. The diversion of the Bicester Road will also disrupt overland surface water flow paths. Overland surface water flow to the west of the

road diversion will be directed in drains at the toe of the embankment to a balancing pond. Flows from the east of the road diversion will be collected and pass beneath the embankment in a culvert. Surface water from both of these drains will then pass beneath the Proposed Scheme in a culvert. Balancing ponds are proposed in this location to manage surface water runoff from the Proposed Scheme with the outfall of the pond discharging into a culvert beneath the embankment to the north. All culverts and land drainage elements will be sized to convey the 1 in 100 years return period (1% annual probability) event including an allowance for future climate change, siltation and blockage.

8.3.10 No increased risk of flooding upstream of the Proposed Scheme will result. There will consequently be no impact on the risk of flooding to Hunters Farm Industrial Estate and Fleet Marston Farm, or the risk of flooding from the downstream watercourses.

8.4 Impact on risk of flooding from groundwater

8.4.1 There will be two below ground construction elements within CFA11: the Aylesbury south and Aylesbury north cuttings. The Proposed Scheme is not expected to have any significant long-term impacts on groundwater levels within the bedrock aquifers within the study area although slight effects may be observed within the Portland Sand formations due to the Aylesbury north cutting. These effects are detailed within the CFA11 Water Resources Assessment (Volume 5: Appendix WR-002-011). The Portland Sand aquifers are shown on the BGS susceptibility to groundwater flooding maps to have low and very low susceptibility to groundwater emergence. The Aylesbury north cutting will pass through these areas of susceptibility and could therefore potentially affect the localised risk of groundwater flooding. The potential overall effects of the cutting on groundwater flows, however, are assessed to be slight and there is unlikely to be a sufficient increase in bedrock groundwater levels to increase the susceptibility to moderate or greater. In addition, any localised emergent groundwater will be intercepted by the land drainage and discharged via local watercourses. Consequently, there will be no significant impact on the risk of flooding from groundwater in the bedrock aquifers.

8.4.2 The Aylesbury south cutting will potentially obstruct groundwater flows in the superficial deposits along the Stoke Brook valley. These are areas of 'high' and 'very high' susceptibility to groundwater emergence. The Proposed Scheme, however, will pass along the south-western edge of the deposit area and as a result groundwater flow obstruction will be minimal. Due to the small spatial extent of the aquifer the extent of the cutting will remove significant areas of storage from the deposits. It is, however, not anticipated that the cutting will be sealed and consequently groundwater will be collected into the Proposed Scheme drainage and discharged via balancing ponds to the local watercourses. As a result, no significant increase in the risk of groundwater flooding is anticipated upstream of the Proposed Scheme. Properties on Harbourne Close, Deverill Road and Oat Close lie within the same area of 'very high' susceptibility. These are, however, on the opposite side of the Stoke Brook valley and are consequently not expected to be affected by the Proposed Scheme. There are no other formal receptors within the area at risk.

8.5 Impact on risk of flooding from drainage systems

8.5.1 The Proposed Scheme will not pass through any urban areas for the full extent within CFA11. All highway crossings required will be diverted or re-designed as bridges or underpasses with the exception of those that will be crossed on viaduct, which will remain unchanged. Highway drainage for all new or realigned roads will be designed in accordance with the relevant design guides and regulations and consequently no increase in the risk of flooding arising from overloaded highway drains is anticipated.

8.6 Impact on risk of flooding from artificial sources

8.6.1 Where the Proposed Scheme intersects the area with a residual risk of impounded reservoir failure, it will be on viaduct for the crossing of the Thame Valley. The modelled extent of the residual risk of reservoir failure is shown to be within the extent of the floodplain of the River Thame. The length of the viaduct has been designed to span the floodplain and therefore no embankments will be constructed within the reservoir flood risk area.

8.6.2 The Environment Agency online mapping only displays the residual risk of failure of artificial water bodies with a capacity above 25,000m^3, which are covered under The Reservoirs Act 1975 (as amended). This requires water companies to maintain their reservoirs such that the annual probability of a breach of the reservoir is 1 in 50,000. Although there is a potential impact on the residual risk of flooding from the reservoir the likelihood of such flooding occurring is extremely low. Further, mitigation measures employed against the potential impact on flooding from the River Thame will additionally apply to the risk of flooding from the Tring Reservoirs.

8.6.3 The impact of the Proposed Scheme on the actual risk of flooding from impounded reservoir failure will be negligible.

8.7 Summary of potential impacts and effects on flood risk

Table 11: Summary of potential flood risk impacts and effects in CFA11

Receptor	Vulnerability classification	Pathway	Effects
General Proposed Scheme	N/A	River flooding	Significant changes in hydraulics along the Stoke Brook, no overall effect expected. No significant impact on the risk of flooding from Sedrup and Hartwell ditches. Minor afflux and floodplain displacement at Thame Valley viaduct.
		Surface water	Potential minor effects due to collection of overland flows into formal drainage systems.

Receptor	Vulnerability classification	Pathway	Effects
		Groundwater	Alterations in groundwater regime in superficial aquifers arising from Aylesbury embankment are unlikely to increase the risk of groundwater flooding elsewhere due to collection of groundwater into the drainage system. Potential changes in bedrock groundwater flows due to Aylesbury embankment are unlikely to lead to increased risks of groundwater flooding, due to low and very low susceptibility classifications.
		Drainage systems	No effects expected.
		Artificial sources	Potential afflux upstream of Thame Valley viaduct in the event of failure of Tring reservoirs though effect expected to be less than corresponding river flooding effects.
Stoke Grove Farm	More vulnerable	Surface water 30 years - deep	No significant effect due to maintenance of downstream flow volumes and distance of receptor from Proposed Scheme.
Bucks Goat Centre	Less vulnerable	Surface water 200 years - shallow	No significant effect due to maintenance of downstream flow conveyance.
Old Risborough Road houses	More vulnerable	Surface water 200 years - shallow	No significant effect due to maintenance of downstream flow conveyance.
The Paddock	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep	No significant effect expected on the risk of flooding from the Stoke Brook therefore no significant effects expected.
Brook Farm	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep	No significant effect expected on the risk of flooding from the Stoke Brook therefore no significant effects expected.
Moat Farm	More vulnerable	River flooding Flood Zone 3 Surface water 30 years - deep Groundwater - very high	No significant effect expected on the risk of flooding from the Stoke Brook therefore no significant effects expected.
Aylesbury Town	More vulnerable	Groundwater - very high	No significant effect as the receptor is on the opposite side of the Stoke Brook valley.
Sedrup Lane residential area	More vulnerable	Surface water 30 years - shallow	No significant effect due to maintenance of downstream flow volumes and distance of receptor from Proposed Scheme.

Receptor	Vulnerability classification	Pathway	Effects
Hartwell House and parkland	More vulnerable	Surface water 30 years - shallow Groundwater - very high	No significant effect due to maintenance of downstream flow volumes and distance of receptor from Proposed Scheme.
Aylesbury Park Golf Club	Less vulnerable	River flooding Flood Zone 2 Surface water 30 years - shallow Groundwater - very high	No significant effect dues to provision of replacement floodplain storage to offset any loss of floodplain resulting from the Oxford Road embankment and Footpath SBH/32 overbridge.
Upper Hartwell village	More vulnerable	Surface water 200 years - shallow	No significant effect due to maintenance of downstream flow volumes and distance of receptor from Proposed Scheme.
Lower Hartwell village	More vulnerable	Surface water 30 years - deep Groundwater - very high	No significant effect due to maintenance of downstream flow volumes and distance of receptor from Proposed Scheme.
Fairford Leys flood storage area	Water compatible	River flooding Flood Zone 3 Surface water 30 years - shallow Tring reservoirs failure	Loss of flood storage capacity due to viaduct piers. Replacement floodplain storage provided to offset any impacts and ensure no significant effect.
Putlowes	More vulnerable	Surface water 30 years - shallow	No significant effect due to distance of receptor from Proposed Scheme and viaduct construction.
Hunters Farm industrial estate	Less vulnerable	Surface water 30 years - shallow - and 200 years - deep Groundwater - very high	No significant effect due to collection of overland flow and controlled discharge.
Upper Cranwell Farm	More vulnerable	Surface water 200 years - shallow	No significant effect due to maintenance of downstream flow volumes and distance of receptor from Proposed Scheme.
Fleet Marston Farm	More vulnerable	Surface water 30 years - shallow - and 200 years - deep	No significant effect due to collection of overland flow and controlled discharge.

9 Conclusions

9.1 Summary

9.1.1 The Proposed Scheme within the study area extends from just north of Nash Lee to exit the area south of the A41 Bicester Road. The study area includes all areas within 1km of the Proposed Scheme which includes areas at risk of flooding from all sources as follows:

- areas at risk of river flooding from the Stoke Brook, the Sedrup and Hartwell ditches and the River Thame;
- areas at risk of flooding arising from direct runoff of rainfall, together with three minor watercourse crossings;
- areas susceptible to groundwater emergence and thus at risk of groundwater flooding, one of which coincides with an area of below ground level construction under the Proposed Scheme; and
- an area at risk of inundation should the Tring Reservoirs fail.

9.1.2 The Proposed Scheme will be at least 1m above design flood water levels within all areas at risk of flooding from rivers, drainage and artificial water body sources. Residual risks from these sources will be negligible. There is one instance where the Proposed Scheme will be in a cutting in an area with a very high susceptibility to groundwater emergence. Emergent groundwater will be collected into the Proposed Scheme drainage system and discharged via balancing ponds to local watercourses. Design standards are such that no flooding of the Proposed Scheme is expected under normal operating conditions.

9.1.3 The dominant land use within CFA11 is agriculture. Excluding areas of farmland adjacent to the Proposed Scheme, there are no third party receptors that will be significantly affected by the Proposed Scheme.

9.2 Residual flood risks to Proposed Scheme

9.2.1 Residual flood risks arise in situations that are not included in standard design scenarios, for example when a culvert becomes blocked causing flooding upstream. All design is generally undertaken assuming that existing infrastructure is functioning under normal conditions. Consequently, there may be areas where the potential severity of flooding may exceed the design standard under certain circumstances.

Residual flood risks from rivers

Stoke Brook

9.2.2 There are a number of existing hydraulic structures along the Stoke Brook within the study area. Upstream of Risborough Road all existing structures will be removed and there are therefore no additional residual risks to the Proposed Scheme. Remaining structures on the Stoke Brook which could create a residual risk of flooding to elements of the Proposed Scheme are as follows:

- Risborough Road culvert- according to the hydraulic model there is a headroom of approximately 1m and 0.6m within the culvert during the 1 in 100 years return period (1% annual probability) flood event including an allowance for climate change and the 1 in 1,000 years return period (0.1% annual probability) flood event respectively and blockage is therefore extremely unlikely; and
- Marsh Lane culvert - blockage of the Marsh Lane culvert would result in an increased risk of flooding to the Footpath SMA/9 accommodation overbridge. The proposed overbridge, however, results in a reduction in overall flood risk to the PRoW and a corresponding reduction in the residual risk, since the path will be raised above existing levels.

Residual flood risks from surface water and minor watercourses

9.2.3 All culverts within the Proposed Scheme are designed with a minimum of internal headroom of 600mm above the design flood water level to minimise the risk of blockage. There is therefore not expected to be any significant increased risk of flooding at minor watercourses and dry valley crossings arising from potential blockage of culverts.

9.2.4 There are no watercourse crossings within CFA11 where significant hydraulic structures exist within a reasonable hydraulic distance either upstream or downstream, which could create significant additional risks of flooding to the Proposed Scheme due to blockage or failure.

Residual flood risks from groundwater

9.2.5 Groundwater levels rise and fall relatively slowly and for any change to occur in the risk of flooding from this source, below ground intervention is necessarily required. The risk of flooding from groundwater already considered therefore presents an absolute risk and there are no significant residual risks arising from this source.

Residual flood risks from drainage systems

9.2.6 Blockage of underground surface water collections systems can cause surcharge and associated flooding. There are no risks of flooding to the Proposed Scheme from drainage systems associated with existing infrastructure within CFA11.

Residual flood risks from artificial and surface water bodies

9.2.7 Within CFA11, the only area of flood risk associated with an artificial or surface waterbody is the inundation area associated with failure of the Tring Reservoirs. The Environment Agency methodology considers the consequences of total failure of the reservoir and therefore no further residual risks arise.

9.3 Residual effects of the Proposed Scheme on flood risk

9.3.1 Following mitigation for impacts on the risk of flooding arising from the Proposed Scheme, there will be slight residual effects on the risk of flooding due to changes to geometry, floodplain flow characteristics and river morphology at the Stoke Brook and River Thame. Such effects will be limited to the reshaping of floodplain extents

arising from replacement floodplain storage and watercourse diversions with no overall residual effects on additional third party receptors.

9.3.2 All culverts within the Proposed Scheme are designed to convey the 1 in 100 year (1% annual probability) flow including an allowance for climate change with a minimum of internal headroom of 300mm above the design flood water level to minimise the risk of blockage. Consequently, there will be a negligible increase in upstream residual flood risks arising from the introduction of culverts within the Proposed Scheme.

9.4 Compliance with local planning policy

9.4.1 The Proposed Scheme includes an allowance for future increases in the risk of flooding as a result of climate change by adding a 20% increase to design river flows and a 30% increase to rainfall intensities and flows in minor watercourses as recommended in the NPPF Technical Guidance document. SuDS are used throughout the design in the form of balancing ponds and swales as well as the creation of open channel land drainage. The Proposed Scheme will be in compliance with the BuCC LFRMS. Collected surface water will discharge directly to local watercourses in accordance with the Aylesbury Vale Water Cycle Strategy.

9.4.2 Although not in direct contravention of the Thames region CFMP, the introduction of additional culverts is at variance with the general aims of the Thames region CFMP which seeks to restore culverted watercourses and enhance natural floodplain. In addition, the AVDC SFRA stipulates that proposed infrastructure should avoid interference with floodplain flows and storage unless designed specifically with a flood risk management function incorporated. As part of the Proposed Scheme, where losses in natural storage capacity are identified, mitigation will be provided in the form of replacement floodplain storage. Although minimised wherever possible there is no practical way to avoid culverting and floodplain or valley flow obstruction due to the linear nature of the Proposed Scheme.

9.4.3 The incorporation of allowances for climate change in the design of the Proposed Scheme ensures compliance with the Vale of Aylesbury Plan, Objective 7. A number of watercourses will, however, be culverted, resulting in potential losses in watercourse quality (refer to WR-002-012 and the route-wide water framework directive (WFD) assessment) and natural floodplain storage, which is contrary to the overall aims of Objective 7, as well as Policy VS11.

10 References

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